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FACTORS INFLUENCING MECHANICAL PROPERTIES OF POLYURETHANE FOAMS USED IN COMPRESSIBLE FLEXOGRAPHIC SLEEVES

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Introduction

Packaging is nowadays, a multi-disciplinary field, a rapidly evolving science and a dynamic industry with continuous positive indicators, with the print quality being determined by many factors connected with printing process (Izdebska, 2015). Manufacturers of flexographic printing components are focused towards development of new printing plates, inks, anilox engraving techniques, stickyback tapes and sleeves, all of which have a significant impact on the product quality.

Sleeves are comprised of hard base often covered with compressible polyurethane (PU) foam layer. PU foam layer can have different composition and level of porosity which are the main factors influencing compressibility of the sleeve and therefore its area of use. Sleeves are also one of the least researched components in the flexographic printing process. However, mechanical properties of the polyurethane, its fatigue, lifespan and parameters influencing all of them have been extensively investigated in different areas and for different types and formulations of polyurethane. These materials combine durability and toughness of metal with the elasticity of the rubber, making them suitable alternatives for metal, plastic or rubber in different products (Rafiee, 2015; Priscariu, 2011). They have outstanding capability of recovery from the compression or tension stress, and can withstand exposure to a large number of environment factors (Chattopadhyay and Webster, 2009).

Discussion

Density is mass of substance per its unit of volume. It is most often expressed in g/cm3, while its values can be obtained from the sample of any size. Density is not correlated to the size of pores. Density is also not a measure of strength, stiffness or load-bearing capacity.

The density of the foam is controlled by the amount of gas released during the reaction of water with the isocyanate.

(De Vries, 2009) through research defined the influence of relative foam density on the stress-strain curve. As the density increases, so does the Young's modulus, the plateau modulus, and the elastic collapse stress, and the strain at which densification begins decreases.

The yield strength increases by almost 100% with an increase in foam density of only 20% (Lu et al, 2016).

According to the authors (Alzoubi et al, 2014), the elastic properties depend on the relative density of the foam, the shape and size of the cross section of the struts, the Young's modulus and the Poisson's ratio.

It has been experimentally proven that hysteresis and reduction of stress due to fatigue decrease with increasing foam density.

In addition to the strain levels, the strain rate can have a large influence on the mechanical properties of the polymer. One of the most important characteristics used to evaluate the mechanical properties of a material is the stress-strain curve.

(Lu et al, 2016) experimentally concluded that the Young's modulus and the elastic buckling stress of the foam are obviously dependent on the strain rate. During the unloading, hysteresis behavior is noticeable, where the unloading strain is late compared to the stress, but after a sufficient time it returns to zero with a small permanent deformation.

A large number of studies involving the microstructure of open-cell foams have shown that most of the cells within the foam are to some extent elongated in a certain direction originating from the production process.

(Koohbor et al, 2018) showed that under conditions where there is no significant influence of the strain rate on the strength and modulus of elasticity of the parent polymer, elastic buckling and failure due to brittleness inside the thinner cell walls become competing failure modes. They proved that as the strain rate increases, so does the difference between the critical stresses for all material failure modes. Thus, although the failure mode due to brittleness (Figure 1. c) is the main failure mode for all strain rates, the chances of failure occurring due to elastic buckling (Figure 1. a) and/or plastic collapse (Figure 1. b) grow. The overlap of these modes at higher strain rates occurs due to a significant increase in the yield strength of the parent polymer.

If the density is low, foams with open cells are deformed primarily by bending the cell walls. With increasing relative density, the contribution of stretching or compression of cell walls becomes more significant.

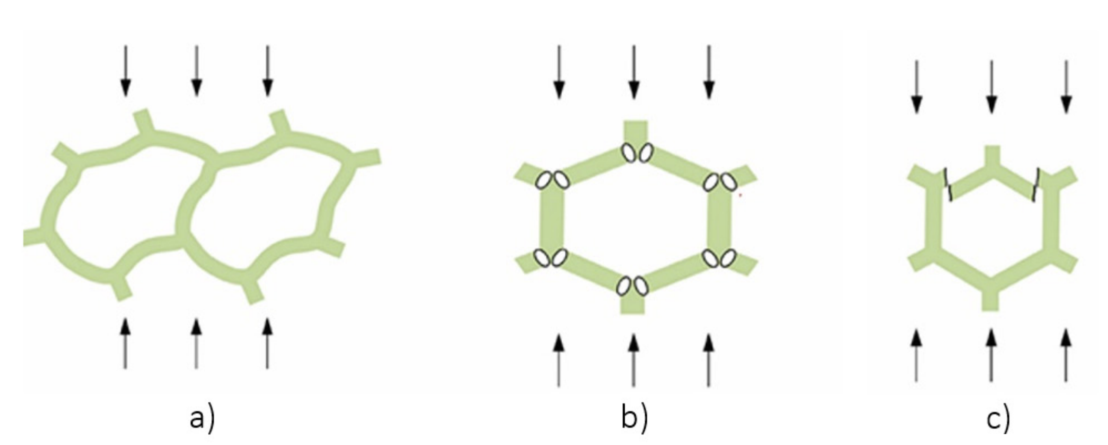

Figure 1

Representation of cell deformation due to a) elastic buckling; b) plastic collapse; c) brittleness (Koohbor et al, 2018)

(Tobushi et al, 2002) investigated the phenomena of creep and stress relaxation of polymer memory foam. They concluded that the creep is higher if the initial strain is smaller.

The level of stress relaxation also depends on the history of material deformations and temperature fluctuations during measurements (Derham, 1973).

(Qi and Boyce, 2005) during loading and unloading of materials periodically paused testing for 60s at strain levels of 20%, 40%, 60% and 80% and measured the stress response, i.e. stress relaxation at constant strain. During loading, the stress decreased in the strain retention phases, while during unloading the stress increased in the retention phases.

(Petrů and Novák, 2017) subjected different types of polyurethane foams to strain levels of 10%, 25%, 50%, and 65% over duration of 3600s while measuring stress relaxation. Their research concludes that regardless of the type of polyurethane foam, stress relaxation increases with increasing initial strain.

Conclusion

Knowledge of the factors influencing PU foam properties enables further research regarding characterization of the flexographic sleeves. The review of the existing literature regarding mechanical properties of the PU foams makes it possible to select the parameters with the greatest possible influence on the flexographic printing process, as well as to find the most suitable methods to investigate the effect of exploitation on sleeve properties. Another benefit lies in the knowledge of mechanisms of PU foam structure deformation which makes it possible to find the main causes of change in mechanical properties of the sleeves originating from the plate mounting/demounting and the printing process. As a large number of parameters influencing PU foam mechanical properties are fixed during printing, it can be concluded, through the review of the existing literature, that the main parameters to be investigated are the resilience of the sleeve compressible layer during cyclic compression testing (residual strain), maximum stress, Young's modulus, hysteresis loss, and creep and stress relaxation during cyclic compression testing with strain retention. These parameters should be selected as they are the ones mostly influenced by the changes in the PU foam structure and mechanical properties after exploitation.

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